Storm Water Modeling and Infrastructure Mapping Project

Presented to

City of Bryan

THOMPSON

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J.F. Thompson, Inc. (herein referred to as Thompson; formerly Thompson Professional Group, Inc.) was authorized on August 14, 2001, to perform engineering services for the City of Bryan's (City) *Storm Water Modeling and Infrastructure Mapping Project, Phase II*. The scope of work for this project included:

1) Field Surveying
2) Condition Assessment
3) Surveying/Assessment Data Preprocessing
4) GIS/Mapping
5) Drainage Area Delineation
6) Hydrologic and Hydraulic (H&H) Modeling
7) Capital Improvement Plan (CIP) Development
8) Field Visits
9) Technical Training

The following discussion further explains the project tasks and the methodology employed.

1.) FIELD SURVEYING

As defined for the Pilot Area in Phase I of this project, the primary survey efforts were focused on the storm sewer system. Detailed surveying tasks included:

- Establishing horizontal and vertical controls for the entire City's storm sewer infrastructure with Global Positioning System (GPS)
- Obtaining inlet/manhole location and elevation information, including gutter line elevations at the inlets, manhole rim elevations, back of curb elevations, and adjacent natural ground elevations
- Obtaining culvert and/or bridge location and elevation data, such as upstream and downstream deck elevations at centerline, flowline elevations, and adjacent natural ground elevations
- Obtaining channel cross-section geometry information approximately 20 feet upstream and downstream of each culvert and bridge, including elevations of flowline, toes, and banks

2.) CONDITION ASSESSMENT

A condition assessment was performed along with the field surveys to determine the existing condition of each feature. The specific items obtained during this task included:

- Collecting and reviewing storm sewer system maps and as-built drawings

- Based on the Condition Assessment Form rating system as defined in Phase I for the Pilot Area, determining the existing conditions of each feature (inlet, manhole, culvert/bridge, outfall, and channel junction); identifying the type and material of each feature; defining the connectivity of the system at each manhole; and measuring the manhole depth from the rim elevation
- Taking digital photographs of all visible portions of each feature where condition assessments were made

Note that no internal inspections or smoke tests were performed.

3.) SURVEYING/ASSESSMENT DATA PRE-PROCESSING

Surveying and assessment data were pre-processed before being GIS-mapped. Field surveying data was first processed in order to geocode surveyed inlets, manholes, culverts, bridges, outfalls, and channel junctions in the GIS workspace. Assessment data for each feature class was loaded into an Access Assessment Database in order to be joined with corresponding geocoded features and displayed in the GIS for query and H&H analysis. This pre-processing procedure ensured accurate geocoding of each feature class in the GIS and combining of the assessment attribute data to its corresponding geocoded feature.

4.) GIS/MAPPING

A database view was created in ArcMap. The storm sewer information, pipes, manholes, inlets, outfalls, etc. were added to the view as layers. The drainage area delineation and City base data were imported from Microstation files into the GIS database and represented in the view. Other data such as hydrography and contours were also added. The storm sewer network data was exported from the GIS and used for H&H analysis. The results of the H&H analysis revealed pipe links that required improvement. A pipe improvement feature layer was created by merging the H&H output and the pipe feature data. This pipe improvement layer was then added to the view. Aerial photography was incorporated to provide a "bird's eye" view for the user. From this view, the user can view the data and perform attribute and spatial queries to learn about the data contained the GIS database.

5.) DRAINAGE AREA DELINEATION

Based on the 3D contour data provided by the City, the surveying point data, assessment information, available construction plans, and aerial photography, a delineation of drainage areas was performed for the remainder of the City. Every drainage area within each of the six watersheds was delineated to correspond to a storm sewer inlet, pipe culvert, channel junction, or node of interest. The resulting boundary's corresponding area, flow length and associated time of concentration, and percentage imperviousness were also determined, with reference given to the aerial photographs.

Hydrologically speaking, the project's drainage areas encompassed six watersheds that were serviced by six key streams with the following associated area:

1) Briar Creek	2.65 sq. mi. (1696 acres)
2) Burton Creek	5.35 sq. mi. (3424 acres)
3) Carter Creek	5.32 sq. mi. (3405 acres)
4) Cottonwood Branch	3.11 sq. mi. (1990 acres)
5) Hudson Creek	2.79 sq. mi. (1786 acres)
6) Turkey Creek	2.09 sq. mi. (1338 acres)

6.) HYDROLOGIC & HYDRAULIC (H&H) MODELING

Similar to Phase I for the project's Pilot Area, the resulting drainage systems were hydraulically modeled using XP-SWMM, a proprietary version of the Environmental Protection Agency's (EPA) Storm Water Management Model (SWMM). The SWMM model is a comprehensive mathematical model developed for both continuous and single event simulation and was used to measure runoff quantity in the storm sewer systems. The overall H&H modeling procedures included four steps: rainfall distribution, GIS-assisted model creation, model calibration, and model implementation.

A.) RAINFALL DISTRIBUTION & RUNOFF

To be consistent with the Brazos County Flood Insurance Study (FIS), the HEC-1 model for the Briar Creek watershed was obtained from the City and used to generate a 10-year frequency (10% recurrence interval) input hyetograph for use in the hydrologic or RUNOFF block of the XP-SWMM model.

This 10-year frequency rainfall distribution (centered on hour 12 of a 24-hour rainfall event) was simulated in the RUNOFF module of XP-SWMM. The U.S. Soil Conservation Service's SCS Method was then used to develop runoff hydrographs for each drainage area, as set forth in the SCS National Engineering Handbook, Section 4 (NEH-4). The SCS method of hydrograph development uses the following four separate parameters to determine the amount of excess runoff to be used for a given drainage area: 1) the pervious area Curve Number (CN); 2) the curve shape factor; 3) the time of concentration (TC); and 4) the initial soil abstraction. The CN is a dimensionless number depending on the hydrologic soil group, cover type, treatment, hydrologic condition, and antecedent moisture conditions, and ranges from 0 to 100. For the City of Bryan, a CN of 80 was determined to be appropriate based on local conditions. The Soil Conservation Service has determined that a hydrograph shape factor of 484 is appropriate for most watersheds; as a result, this value was used for this project. The TC was calculated conventionally by Thompson using the longest travel path and an appropriate overland, gutter, and ditch velocity. These TC values were then manually entered into XP-SWMM. The final element used in the SCS method was the initial abstraction. The fraction value of 0.2 was used to calculate the runoff.

B.) GIS-Assisted Model Creation

The GIS and database provided the physical/hydraulic data needed by the XP-SWMM model, including links (or pipes) between inlets and manholes as well as channel junctions, and attributed information such as diameter of pipe or box dimensions, material type, shape, roughness, flowline elevations, dimensions and conditions of inlets and manholes, culverts, and bridges. For most commercial GIS packages, there are no readily available functions that export data parameters needed for stormwater modeling. An application program was developed by Thompson to provide the H&H modeling interface with the GIS/database.

C.) Model Calibration

A properly calibrated and verified simulation is the cornerstone of H&H modeling and is invaluable in understanding the present behavior of an existing system and in further developing improvement options for any hydraulic problem. The H&H models were carefully observed to ensure that reasonable rainfall runoff, outflow, and water surface elevations resulted from each run. Accordingly, areas of known flooding problems were compared to the modeling results to ensure that the "real world" was being properly simulated.

D.) Model Implementation

After calibration, the models were applied to the remaining area to simulate the performance of the existing systems and to identify any hydraulic inadequacies. A hydraulic inadequacy was determined to occur when the drainage system was unable to convey the runoff from 10-year frequency conditions, that is, when the hydraulic grade line (HGL) exceeded the surveyed gutterline. Inlets were not modeled; in other words, drainage areas were routed directly to the upstream node of the XP-SWMM link representing the culvert/sewer/roadside ditch. In each model where existing inadequacies were detected, the XP-SWMM node was highlighted green to denote that "flooding" occurred. Note that the term "flooding" refers to the fact that the gutterline was exceeded, and does not refer to any measure of ponded depth in the roadway or roadside ditch. When hydraulic inadequacies were detected, the existing condition XP-SWMM model was subsequently "saved as" and proposed modifications were made to the system until adequacy was attained (i.e., the HGL remained at or below the gutterline). Note that assumptions were made in many situations, specifically with regards to existing condition connectivity where the survey and assessment was unclear, and in proposed conditions with regards to proposed slopes and required pipe (or box) cover relative to the surface. Where anticipated pipe/box modifications were proposed, those XP-SWMM links were also highlighted green.

An XP-SWMM file-naming convention was assembled to aid in the GIS user to pinpoint the hydraulic model of a specific feature of interest. Each SWMM filename tracked the following convention:

U/M/L_WATERSHED_OUTFALL_E/P.xp

where:

U/M/L stands for **U**pper, **M**iddle, or **L**ower; that is, a relative position within a watershed;

WATERSHED stands for which watershed boundary the system lies within (i.e., Briar, Burton, Carter, Cottonwood, Hudson, Turkey);

OUTFALL stands for the system specific outfall name (e.g. O4124);

E/P denotes whether the system analyzes **E**xisting or **P**roposed conditions

For example, "M_BURTON_O4124_P.xp" translates that this XP-SWMM file is a proposed analysis of outfall system O4124 located in the middle portion of the Burton Creek watershed.

One hundred thirty-two (132) of the existing 518 storm sewer outfall systems were deemed inadequate, either partially or wholly. When proposed improvements were identified, those data were then uploaded to the GIS to reflect the capital improvement changes recommended from the H&H modeling.

7.) CAPITAL IMPROVEMENT PLAN (CIP) DEVELOPMENT

Capital Improvement Plan (CIP) costing was assembled for proposed improvements identified from the H&H modeling. In an interim review meeting held at the City, reasonable prices and percentages were agreed upon for use in assembling the costing for the proposed improvements. The following assumptions were made:

A.) Proposed pipe/box sewers unit costs were taken from the Texas Department of Transportation's website, specifically from bid tabulations for the Bryan District

B.) Removal of the existing storm sewer was estimated at 10% of the proposed pipe/box sewer

C.) Associated pavement removal was projected to require the removal of two 12-foot lanes at $3 per square yard

D.) 8-inch pavement replacement was estimated for two 12-foot lanes at $30 per square yard

E.) A 25% contingency of the above subtotal (A+B+C+D) was added to account for any other utility replacement required (waterline, sanitary sewer, etc.)

F.) Mobilization was estimated at 10% of the above subtotal (A+B+C+D+E)

G.) Design and project management was projected to be 15% of the above subtotal (A+B+C+D+E+F)

H.) Grand total project cost = (A+B+C+D+E+F+G)

From a cost comparison standpoint, the following table identifies the estimated total costs of the proposed improvements for each watershed and further quantifies the cost per square mile per watershed.

Watershed	Cost	Area (sq.mi.)	Cost per sq.mi.
Briar Creek	$2,861,823	2.65	$1,079,933
Burton Creek	$17,336,327	5.35	$3,240,435
Carter Creek	$2,773,120	5.32	$521,263
Cottonwood Branch	$4,075,138	3.11	$1,310,334
Hudson Creek	$1,189,037	2.79	$426,178
Turkey Creek	$810,156	2.09	$387,634
Total	**$29,045,601**		

The total cost to implement storm sewers to accommodate the 10-year rainfall event Citywide as outlined above is estimated at approximately $29 million.

8.) Field Visits

Field visits were important in verifying the drainage system's components, high points (boundaries), and drainage patterns.

9.) Technical Training

At this time, Thompson anticipates that the City may require further GIS training, specifically with regards to the GIS' query capabilities and integration of this GIS database with other City spatial and tabular databases.